Steps Toward a Large, Space-Based UV/Optical Fizeau Interferometer: The GSFC Fizeau Interferometer Testbed (FIT)

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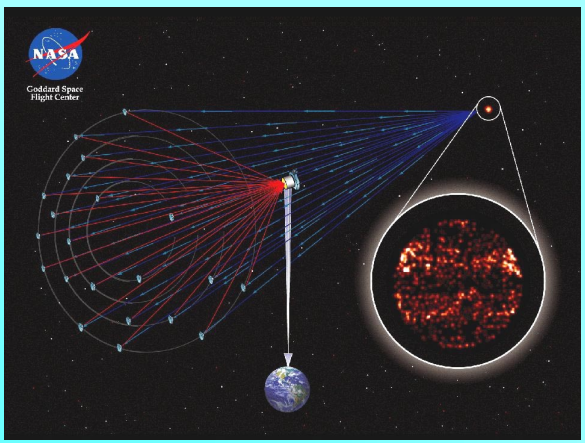
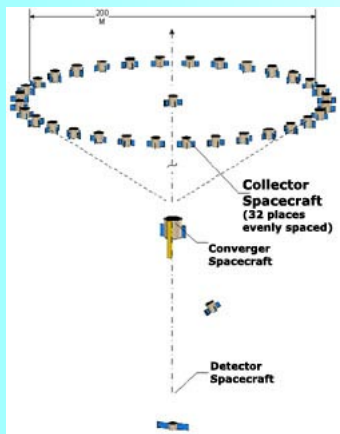
Goals of the FIT

- explore principles/requirements for Stellar Imager & other Fizeau interferometer/sparse aperture telescope mission concepts, to enable their development, reduce technical and cost risks
- utilize 7-30 separate articulated apertures, with tip, tilt, and piston automatically controlled on each
- test multiple configurations of sparse primary array
- validate new and existing analytic and computational models to ensure realistic performance assessment of future flight designs
- demonstrate closed-loop control of system to keep beams phased

Some examples of Future Sparse Aperture Mission Concepts:



Stellar Imager



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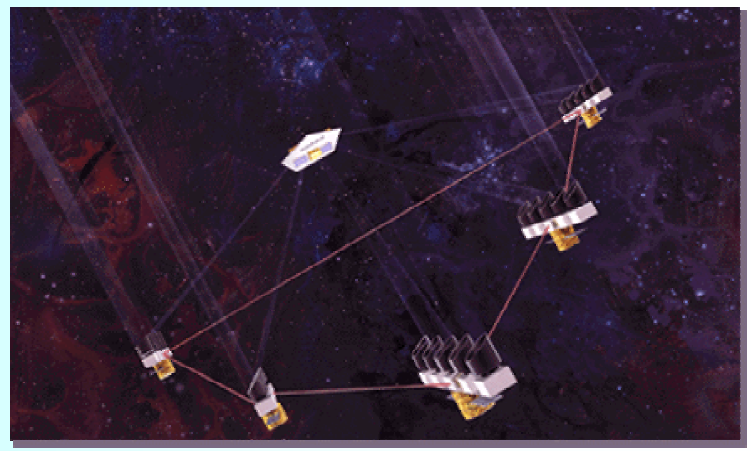
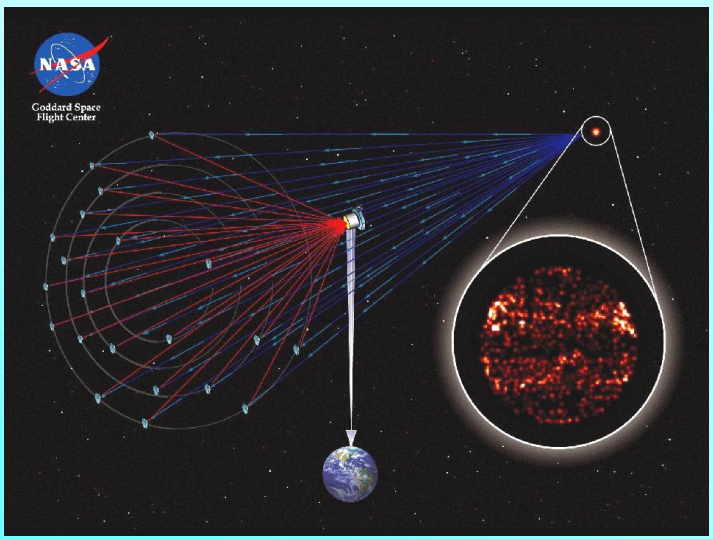


Planet Imager

One Example of a Future Mission Concept Using FIT-type Architecture: Stellar Imager (SI)

- UV-Optical Fizeau Imaging Interferometer
- 30 "mirrorsats" formation-flying with beam combining hub
- Launch > 2015, into Lissajous orbit around L_2
- maximum baseline ~500 m
- => 1000 pixels/stellar image
- Mission duration: 10 years



http://hires.gsfc.nasa.gov/~si

Prime Science Goals

image surface/sub-surface features of distant stars; measure their spatial/temporal variations to understand the underlying dynamo process(es)

enable improved forecasting of solar/stellar activity on time scales of days to centuries

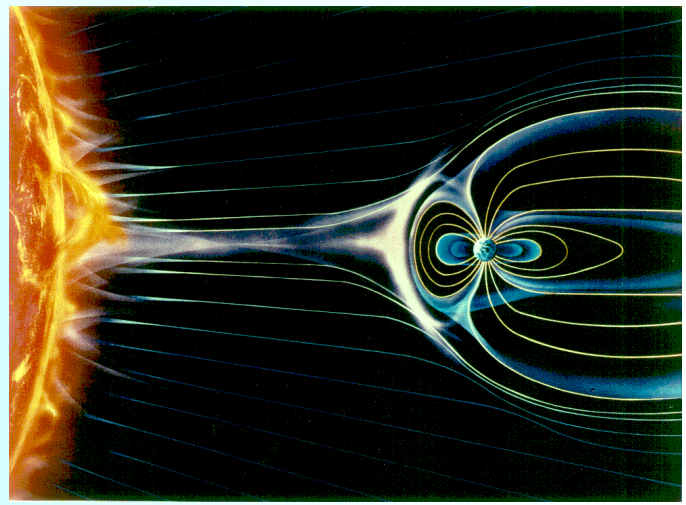
understand the impact of stellar magnetic activity on planetary climates and life

complete the assessment of extrasolar planetary systems found by SIM/TPF, etc.

Additional Science Goals: high resolution studies of Active Galactic Nuclei, Quasars, Supernovae, Interacting Binary Stars, Forming Stars/Disks

Science Drivers for Stellar Imager

- Stellar/Solar Magnetic Activity is key to understanding Life in the Universe & the Habitability of Earth-like Planets. It
  - enables star formation by slowing rotation of collapsing cloud
  - produces energetic radiation => formation of complex molecules
  - governs habitability of biospheres through space weather and its effect on planetary climates

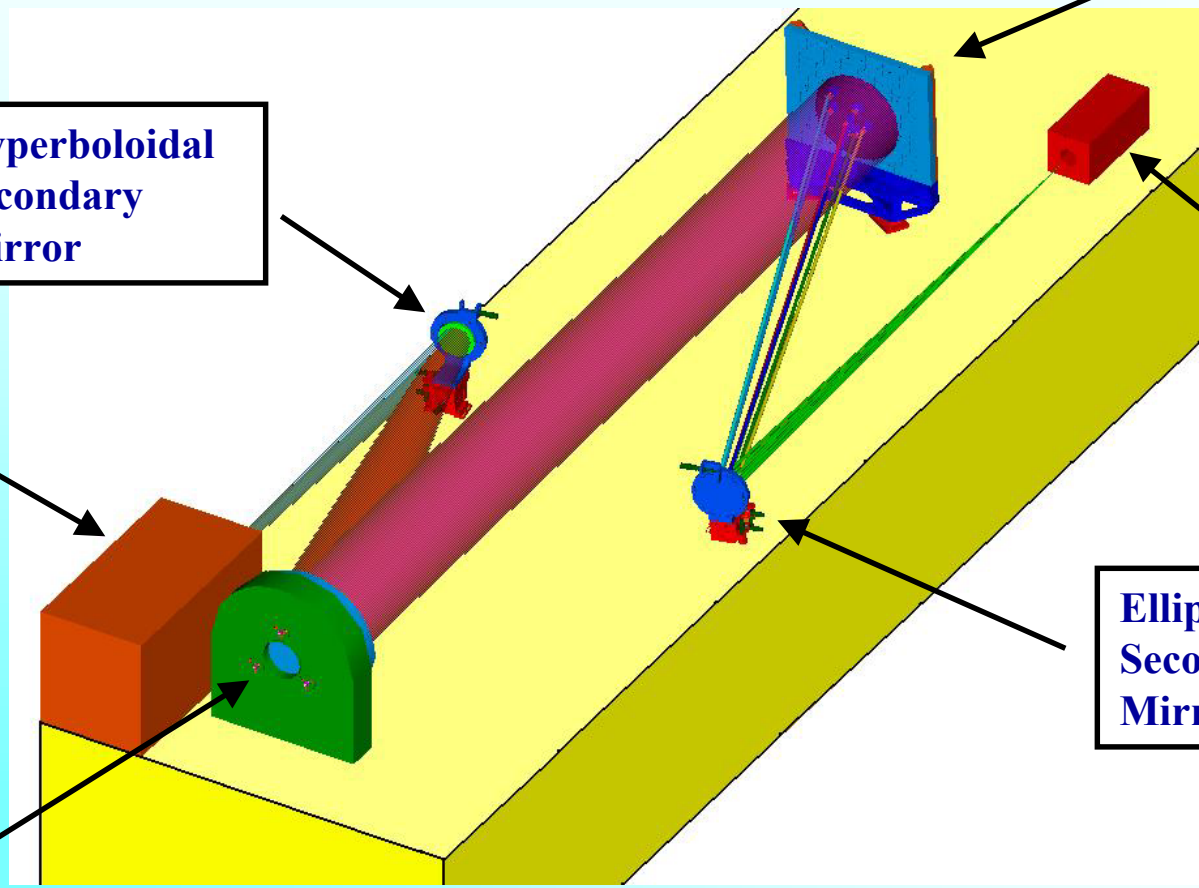


Problem:

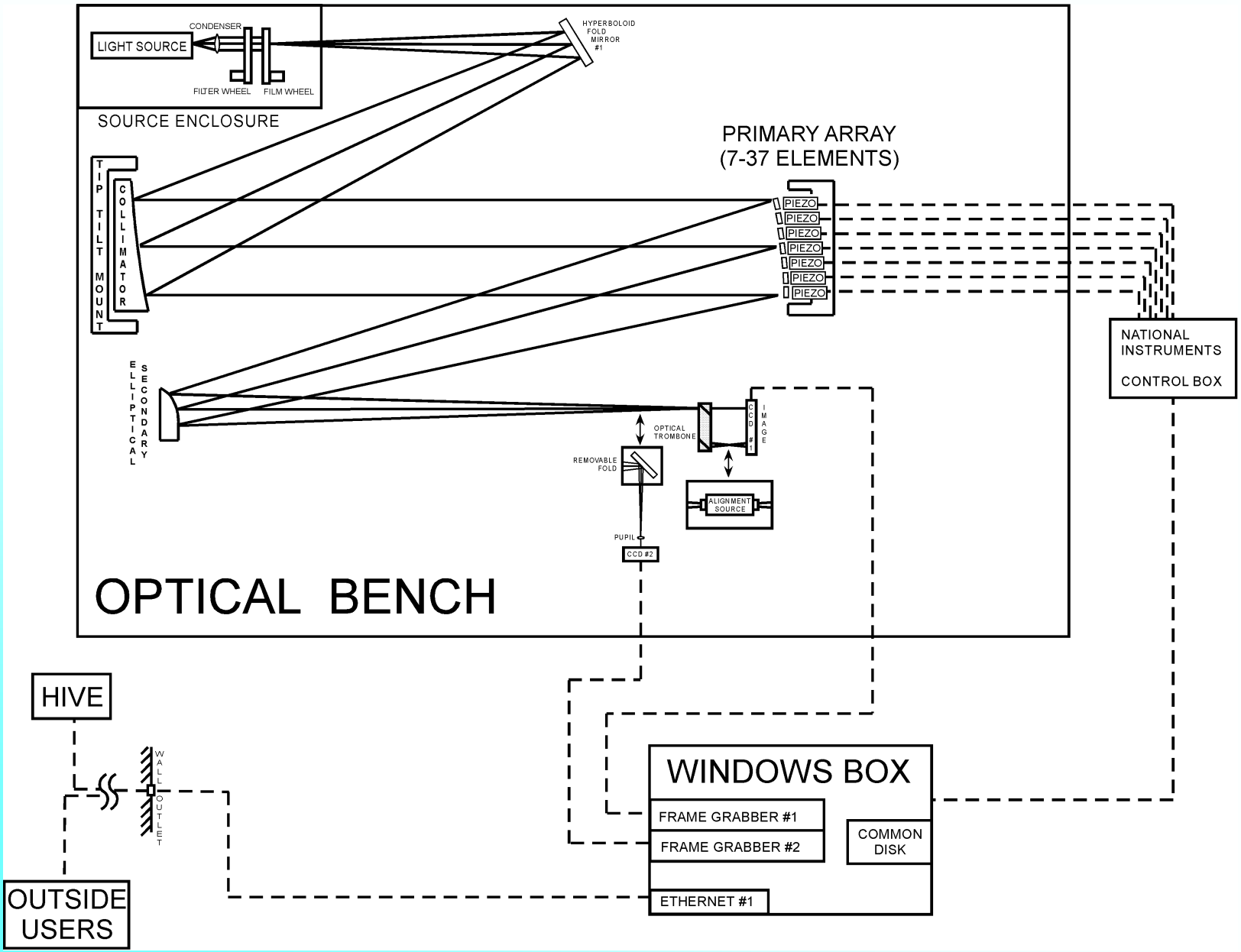
There is no comprehensive model of solar/stellar magnetic activity

- Major progress requires a detailed understanding of stellar dynamos and their behavior in time and with stellar parameters
- High angular-resolution observations of stars over a broad range of activity level needed to refine/constrain dynamo models

Overview of FIT



Block Diagram of FIT

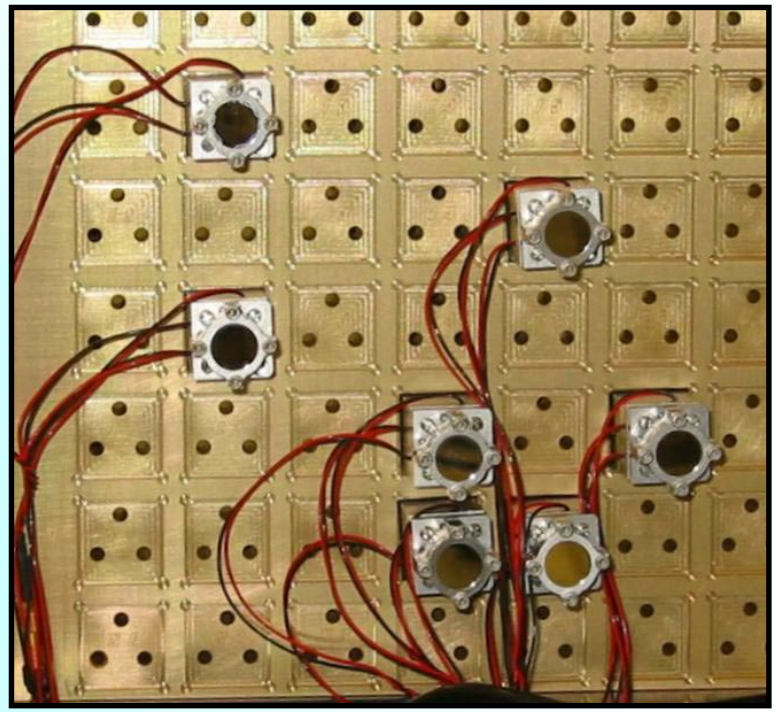


Design Elements (I): Source Enclosure

- Light Sources
  - Zenon (line source), QTH (continuum lamp)
- Filter Wheel
  - slots for both narrow and broad-band filters
- Film Wheel holds
  - test patterns
  - actual solar images
  - synthetic stellar images

Design Elements (II): Optics

- Collimator Primary
  - f/10, off-axis parabola
- Collimator Secondary
  - hyperboloidal mirror
- Imager Secondary
  - off-axis, oblate Ellipsoid
- Primary Mirror Array
  - "sparse aperture" consisting of 7 (Phase I) - 30 (Phase II) 12.5 mm spherical mirrors
  - up to 10" in diameter, configured in minimum-redundancy pattern (e.g., Golay, M.J.E., 1970 J.Opt.Soc.Am., 61, 272)

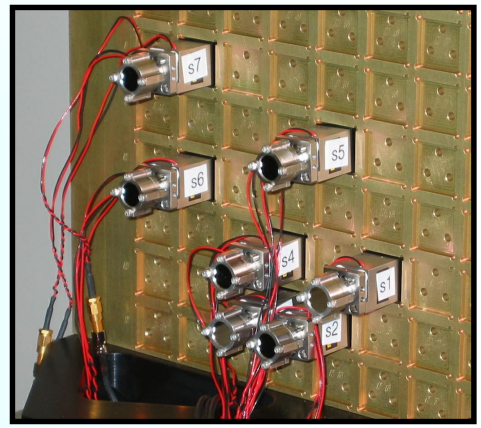


Design Elements (III): Detector System

- Optical trombone and/or fold mirrors direct light to
  - pupil plane monitor
  - science image detector
- Primary detector: CCD camera
  - Finger Lakes CM8
  - 1536 x 1024 pixels,
  - 9 microns in size
  - 4 sec readout time
  - special mod for sub-array readouts in faster time

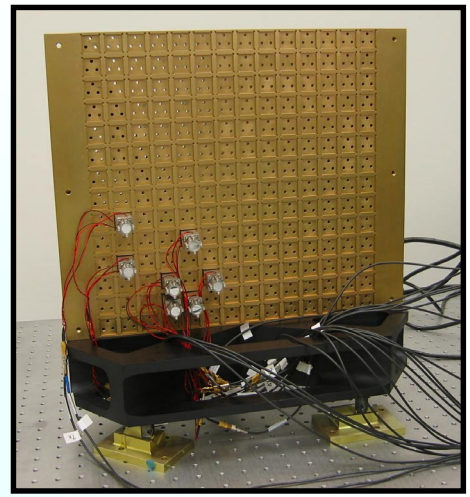
Design Elements (IV): Command & Control Hardware and Software

- Piezo actuators control tip, tilt, piston of primary mirrors
- actuators commanded by (voltage) controller boxes linked to computer via National Instrument cards
- 2 GHz Windows 2000 PC
  - controls data flow from detectors, routes raw science data to Beowulf cluster for analysis, accepts mirror position corrections from Beowulf cluster and commands motion of actuators
- Beowulf cluster
  - 128 nodes, each node has dual Pentium-4 processors
  - perform phase diversity analysis of raw science data
  - generates corrections to mirror position to maintain phasing of all optical paths



Status of the FIT

- Design completed
- Hardware delivered
  - Primary array structure
  - 7 piezo actuators
  - 7 12.5cm primary mirrors
  - collimator mirror
  - secondary mirror supporting structures
- Hardware on order
  - imager and collimator secondary mirrors
- Assembly and initial alignment/calibration of Phase I design (7 mirrors) in progress



Future Plans

- 2003
  - Continue assembly, alignment and calibration of 7-element (Phase I) system
  - begin initial operations and demonstrate closed-loop control of 7-element system
- 2004
  - increase number of primary elements up to ~30, as sufficient experience/success gained with smaller numbers
  - evaluate performance of different array configurations and software algorithms

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